

SYSTEM AND METHOD FOR CONTROLLING
DRILL MOTOR ROTATIONAL SPEED

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to systems and methods for drilling in subterranean zones and, more particularly, to a system and method for controlling drill motor rotational speed.

BACKGROUND OF THE INVENTION

Subterranean drilling operations can expose well bore drilling equipment to severe operating conditions, which may be detrimental to the operating life of the equipment. To maximize drilling efficiency, well bore drilling equipment may be designed to withstand exposure to severe operating conditions for an extended period of time. However, a drill motor's operating life can be substantially affected by exposure to rotational over-speed conditions caused by inconsistencies in the flow of drilling fluid used to power the drill motor. Therefore, it is desirable to prevent or reduce such over-speed conditions.

SUMMARY OF THE INVENTION

The present invention provides a system and method for controlling drill motor rotational speed that substantially eliminates or reduces at least some of the disadvantages and problems associated with conventional systems and methods for controlling drilling.

5 In accordance with certain embodiments, a system for controlling drill motor rotational speed includes a downhole motor disposed in a drill string and having a rotor operable to be rotated by a flow of drilling fluid through the motor. The system also includes one or more by-pass ports operable to allow a portion of the drilling fluid to exit the drill string into a well bore and a governor coupled to the rotor and comprising a valve
10 operable to move in response to the rotational speed of the rotor. The valve movement controls the amount of drilling fluid allowed to flow through the by-pass ports and exit the drill string into the well bore. The valve also directly controls the flow of the drilling fluid into the motor based on the amount of drilling fluid allowed to flow through the by-pass ports, thereby controlling the rotational speed of the rotor.

15 In accordance with certain embodiments, method is provided for controlling drill motor rotational speed. The method includes the step of pumping a drilling fluid through a drill string. The drill string includes a downhole motor, a governor, and one or more by-pass ports. The method also includes the step of rotating a rotor of the motor using the flow of the drilling fluid through the motor. The method further includes the step of
20 moving a valve of the governor in response to the rotational speed of the rotor such that the movement of the valve controls the amount of drilling fluid allowed to flow through the one or more by-pass ports and exit the drill string into the well bore prior to the drilling fluid flowing through the motor to directly control the flow of the drilling fluid into the motor and the rotational speed of the rotor.

25 Technical advantages of the present invention include an improved system and method for controlling drill motor rotational speed to increase the motor's operational life. In particular, a drill motor governor is operable to directly control the flow of drilling fluid into a drill motor so as to control the rotational speed of the drill motor. The use of such a governor can prevent over-speed conditions that frequently occur when using
30 compressible drilling fluids such as air, nitrogen, or foam. Such over-speed conditions can cause excessive wear of the rotor and/or other components of a drill string. Another technical advantage of the present invention includes the ability to allow excess drilling

fluid to enter the well bore to clean the well bore without that drilling fluid passing through the drill motor. Other technical advantages of the present invention will be readily apparent to one skilled in the art from the following figures, description, and claims. Moreover, while specific advantages have been enumerated above, various
5 embodiments may include all, some, or none of the enumerated advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of particular embodiments of the present invention and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which:

5 FIGURE 1 illustrates an example system for controlling drill motor rotational speed;

 FIGURE 2 is a cross sectional diagram illustrating example components of the system of FIGURE 1; and

10 FIGURE 3 illustrates a detailed view of an example drill motor governor of the system of FIGURE 1.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

FIGURE 1 illustrates an example system 10 for controlling drill motor rotational speed. In certain embodiments, system 10 may be used in a well bore 20 extending from surface 25 to penetrate a subterranean zone 30. Although FIGURE 1 illustrates a substantially vertical well bore 20, system 10 may be implemented in articulated wells, slant wells, or any other types of wells or well systems. Subterranean zone 30 may comprise an oil or gas reservoir, a coal seam, or any other appropriate subterranean zone. Subterranean zone 30 may be accessed to remove and/or produce water, hydrocarbons, and other fluids in subterranean zone 30, to treat minerals in subterranean zone 30 prior to mining operations, or for any other suitable purpose.

System 10 includes a drill string 40 used to form well bore 20. In certain embodiments, drill string 40 includes a drill pipe 45, a motor governor 50, a downhole motor 70, a bit box 85, and a drill bit 90. Drill pipe 45 couples to motor governor 50 and runs to surface 25, where it is coupled to pumping equipment to deliver drilling fluid to motor governor 50. Motor governor 50 is coupled to downhole motor 70 and may be used to directly control the flow of drilling fluid into downhole motor 70, thereby controlling the rotational speed of a drill motor contained in downhole motor 70, as described in more detail below with reference to FIGURES 2 and 3. Example downhole motors 70 include turbine motors and positive displacement motors (PDMs), which are well known in the art. Downhole motor 70 is coupled to bit box 85 which provides a mechanical link between downhole motor 70 and drill bit 90, such that the rotational power generated by downhole motor 70 may be transmitted to drill bit 90.

In operation, a drilling fluid, such as drilling mud, is pumped through drill string 40 from pumping equipment located on surface 25, or at any other appropriate location, thereby causing particular components of downhole motor 70 to rotate. This rotation causes drill bit 90 to rotate, thereby facilitating cutting portions of subterranean zone 30 to form well bore 20. Drill bit 90 may be a rotary cone drill bit or any other suitable drill bit. In particular embodiments, drill bit 90 may be replaced with any other suitable rotatable downhole device that is rotated by drill motor 70. The rotation of downhole motor 70 is also used to rotate particular elements of motor governor 50 to directly control the flow of drilling fluid into the inlet of downhole motor 70 and thus control the rotational speed of the drill motor. Although motor governor 50, downhole motor 70, bit box 85, and drill bit

90 are illustrated as having a particular size relative to the other elements of drill string 40, each element 50, 70, 85, 90 may be of any appropriate size as circumstances require.

In certain embodiments, drill string 40 may be used to create well bore 20 to enable access to subterranean zone 30. Subterranean drilling operations can expose well bore drilling equipment, such as drill string 40, to damaging operating conditions. For example, inconsistencies in the flow of drilling fluid, such as entrapped air within the drilling fluid or varying geological conditions may be detrimental to the life of drill motor 70. System 10 may be implemented to provide more efficient drilling operations by providing a system for directly controlling drill motor rotational speed, thereby potentially increasing drill motor operating life, and consequently, the operating life of other drill string components.

FIGURE 2 is a cross-sectional diagram illustrating example components of drill string 40. In the illustrated embodiment, drill string 40 includes motor governor 50, downhole motor 70, bit box 85, and drill bit 90. In certain embodiments, the components of motor governor 50, and downhole motor 70 may be enclosed within drill string pipe walls 42 of drill string 40. The illustrated downhole motor 70 comprises a positive displacement motor (PDM) having a rotor 72 and stators 74. Drilling fluid 100 is pumped into drill string 40 using pumping equipment located on surface 25. Motor governor 50 is operable to directly control the flow of drilling fluid through downhole motor 70, illustrated as fluid 104, and to direct a portion of fluid 100 out of drill string 40 and into well bore 20 illustrated as fluid 102. Drilling fluid 104 is pumped through channels 76 formed between rotor 72 and stators 74. Because of the eccentricity of rotor 72 in stators 74, the flow of fluid 104 imparts a torque on rotor 72 causing rotor 72 to turn.

In certain embodiments, rotor 72 may be constructed of a sufficiently durable and reliable material, such as steel, so that rotor 72 may be disposed within well bore 20 for use over an extended period of time without the need to be removed from well bore 20 for repair or replacement during that time. In certain embodiments, stators 74 may be made from a deformable and resilient material, such as an elastomer, to provide an effective hydraulic seal around rotor 72 while still permitting rotor 72 to turn freely and permitting drilling fluid 104 to flow through channels 76. Rotor 72 and stators 74 may be designed and constructed to withstand the corrosive effects of the minerals and fluids that may be

contained in well bore 20. The use of PDMs in well drilling and the materials and components used to construct PDMs are well known in the art.

Rotor 72 includes a substantially straight shaft portion 73, which extends from stators 74 through downhole motor 70 and protrudes from the end of downhole motor 70, as illustrated in FIGURE 2. Shaft portion 73 is positioned between bearings 79, which may comprise thrust bearings or radial bearings operable to withstand axial and normal loads placed on drill bit 90 during the drilling process and the loads imparted on shaft portion 73 during its rotation. O-rings 77 are positioned within downhole motor 70 around shaft portion 73 to provide an effective hydraulic seal which prevents drilling fluid 104 from flowing through the annulus formed between shaft portion 73 and drill string pipe walls 42. O-rings 77 may be made from a deformable and resilient material, such as an elastomer, to provide an effective hydraulic seal around shaft portion 73 while still permitting shaft portion 73 to turn freely.

In certain embodiments, shaft portion 73 contains one or more fluid ports 80 and a hollow channel 82. Fluid ports 80 allow drilling fluid 104 to flow into hollow channel 82 of shaft portion 73 so that drilling fluid 104 may flow through shaft portion 73 towards drill bit 90. Shaft portion 73 includes bit box 85, which has threads 84 for threadably coupling drill bit 90 to rotor 72. Although threads 84 are illustrated, any other appropriate mechanism for coupling bit box 85 to drill bit 90 may be implemented. Drill bit 90 includes one or more drill cones 92 with a plurality of drill teeth 94. The rotation of rotor 72, and consequently the rotation of shaft portion 73 and bit box 85, rotates drill bit 90, facilitating the removal of material in subterranean zone 30 to form well bore 20. Drilling fluid 104 flows through channel 82 of shaft portion 73 and then flows out of drill string 40 through opening 96 in drill bit 90. In this manner, drilling fluid 104 may be used to remove drill cuttings created by drill bit 90 and to provide lubrication to drill cones 92. The design and construction of the components of drill string 40, such as bit box 85 and drill bit 90, to withstand the corrosive effects of the minerals and fluids that may be contained in well bore 20, is well known.

In certain embodiments, to prolong the operational life of the components of drill string 40, and, in particular, the operational life of the components of downhole motor 70, motor governor 50 may be used to prevent excessive rotational speeds of downhole motor 70. As will be discussed in more detail below with respect to FIGURE 3, motor governor

50 is operable to directly control the flow of drilling fluid 104 entering downhole motor 70, thereby controlling the rotational speed of rotor 72. For example, it is desirable to prevent rotor 72 from exceeding a predetermined rotational speed threshold (a condition known as "over-speeding"). Over-speeding may be caused by an irregularity in the flow of drilling fluid 104 through downhole motor 70. For example, air may become entrapped in drill fluid 104, causing a decrease in fluid resistance. This decrease in fluid resistance may cause the rotational speed of rotor 72 to drastically increase, potentially causing damage to the components within drill string 40. Over-speeding can also be caused by a change in the resistance of the drill bit as it cuts through subterranean zone 30. When drilling subterranean zone material, the torque of drill motor 70 causes drill bit 90 to turn at a given rotational speed. When drill bit 90 is lifted off the bottom of well bore 20 or otherwise loses contact with the subterranean zone material, resistance to the torque provided by drill motor 70 is reduced, thus causing an over-speed condition.

FIGURE 3 illustrates a detailed view of an example motor governor 50 of system 10. Motor governor 50 is operable to control the rotational speed of rotor 72 by directly controlling the flow of drilling fluid 104 entering downhole motor 70. In certain embodiments, motor governor 50 may include a valve apparatus 51 and one or more bypass ports 52 formed through drill string pipe walls 42. Valve apparatus 51 may include a sliding valve 54, a valve post 58, a valve spring 60, valve weights 61, and support members 62, 63. The components of valve apparatus 51 may be designed and constructed to withstand the corrosive effects of the minerals and fluids that may be contained in well bore 20. The use of drill string component materials capable of withstanding the conditions of well bore drilling operations is well known in the art.

In certain embodiments, sliding valve 54 includes valve channels 56 formed through sliding valve 54. Valve channels 56 permit drilling fluid 104 to pass through sliding valve 54 so that the drilling fluid may be used to rotate rotor 72 of downhole motor 70. In certain embodiments, sliding valve 54 may be coupled to valve post 58 or sliding valve 54 and valve post 58 may be constructed as a single component. Valve spring 60 surrounds valve post 58 and is positioned between sliding valve 54 and rotor 72. Support members 62 may be pivotally coupled to sliding valve 54 at one end and pivotally coupled to a valve weight 61 at the other end. Similarly, support members 63 may be pivotally coupled to a valve weight 61 at one end and pivotally coupled to rotor 72 at the other end.

In a particular embodiment, one end of each of support members 63 may be pivotally coupled at the same location on rotor 72. In the illustrated embodiment, rotor 72 includes a slot 78 to receive one end of valve post 58 when sliding valve 54 moves longitudinally towards rotor 72, as indicated by arrow 69a. In an alternate embodiment, where valve post
5 58 is directly coupled to rotor 72 rather than to sliding valve 54, sliding valve 54 may include a slot to receive valve post 58 when valve 54 moves longitudinally towards rotor 72, as indicated by arrow 69a. In certain embodiments, valve post 58 may be omitted from valve apparatus 51.

In operation, rotor 72 rotates as a result of drilling fluid 104 flowing through
10 channels 56 of valve 54 and then through channel 76 between rotor 72 and stator 74. Because sliding valve 54, support members 62, 63, and valve weights 61 are coupled to rotor 72, these components rotate at the same speed as rotor 72. The rotational speed of rotor 72, and consequently, the rotational speed of valve weights 61, may increase due to an increase in the flow rate of drilling fluid 104. In addition, inconsistencies in the flow of
15 drilling fluid 104, such as the presence of entrapped air within drilling fluid 104, may cause a rapid, undesirable increase in the rotational speed of rotor 72 due to the reduced fluid resistance caused by the entrapped air. Likewise, a change in operational or geological conditions could cause the same undesirable increase in the rotational speed of rotor 72. As the rotational speed of rotor 72 increases, the resulting increase in the
20 rotational speed of valve weights 61 causes valve weights 61 to spin faster around the longitudinal axis of drill string 40. The centrifugal force caused by the rotation of valve weights 61 creates an axial force 65 acting through members 62 on valve 54. When axial force 65 exceeds an axial force 66 exerted by valve spring 60 against valve 54, valve 54 will move towards rotor 72.

25 When rotor 72 is not rotating or has a very low rotational speed, sliding valve 54 is positioned to block by-pass ports 52 to prevent the drilling fluid from flowing into well bore 20 through by-pass ports 52. In the illustrated embodiment, as valve weights 61 move laterally outward, axial force 65 causes sliding valve 54 to be moved longitudinally toward rotor 72, as illustrated by arrow 69a, by the closing "scissoring" action of support
30 members 62, 63. Valve spring 60 is compressed between valve 54 and rotor 72, thereby providing axial force 66 opposing the longitudinal movement of sliding valve 54 towards rotor 72. As sliding valve 54 moves in the direction of arrow 69a, sliding valve 54 moves

past by-pass ports 52 creating a pathway for some of the drilling fluid to flow out of by-pass ports 52. As by-pass ports 52 are opened, a portion 102 of drilling fluid 100 flows out of drill string 40 and into well bore 20. Consequently, the flow of drilling fluid 104 to rotor 72 is reduced. Thus, valve apparatus 51 is operable to redirect the flow of a portion
5 of drilling fluid outside of drill string 40 to reduce the flow through rotor 72, thereby reducing its rotational speed and protecting rotor 72 from an over-speed condition which may reduce the operational life of the rotor 72 and the other components of drill string 40. As a result of the re-direction of fluid 100 out of drill string 40 and into well bore 20, the present invention may also act in certain cases as a "dump-sub" which allows excess
10 drilling fluid 100 to enter well bore 20 to clean well bore 20 without fluid 100 passing through drill motor 70.

As the flow of drilling fluid 104 is reduced, the rotational speed of rotor 72 and valve weights 61 decreases. In the illustrated embodiment, at the rotational speed where the axial force 65 acting on members 62 generated through the centrifugal force generated
15 by the rotation of valve weights 61 is exceeded by the axial force 66 of valve spring 60, the axial force 66 applied by valve spring 60 onto sliding valve 54 will cause sliding valve 54 to move longitudinally away from rotor 72, as illustrated by arrow 69b. At the same time, valve weights 61 will be drawn away from drill string pipe walls 42, as illustrated by arrows 68b, due to the opening "scissoring" action of support members 62, 63. As sliding
20 valve 54 moves longitudinally away from rotor 72, it eventually blocks by-pass ports 52 which reduces or completely prevents the flow of drilling fluid out of drill string 40 and increases flow 104 through rotor 72, thus increasing the rotational speed of rotor 72. In this manner, by-pass ports 52 may be blocked and un-blocked as needed to directly control the flow of drilling fluid that enters downhole motor 70 to control the rotational speed of
25 rotor 72.

Therefore, the design of governor 50 regulates the rotational speed of rotor 72 such that it does not exceed a particular rate. The selection of a valve spring 60 having a particular spring constant, valve weights 61 having a particular mass, and support members 62, 63 having particular lengths, are thus matters of design choice based on the
30 desired maximum rotational speed of rotor 72.

In certain embodiments, drill motor governor 50 and by-pass ports 52 may be located at a sufficient distance away from drill bit 90 so that the drilling fluid 102 flowing

into well bore 20 through by pass-ports 52 does not substantially affect the weight-on-bit of drill string 40. Therefore, drill motor governor 50 may control the rotational speed of motor 70 by directly affecting the flow of drilling fluid into motor 70.

5 Although the present invention has been described with several embodiments, a multitude of changes, substitutions, variations, alterations, and modifications may be suggested to one skilled in the art, and it is intended that the invention encompass all such changes, substitutions, variations, alterations, and modifications as fall within the spirit and scope of the appended claims.